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# RECONSTRUCTION OF PAST CLIMATIC VARIABILITY

Harold C. Fritts, et al

Arizona University

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# RECONSTRUCTION OF PAST CLIMATIC VARIABILITY

(A Progress Report)

*sponsored by*

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ARPA Order No. 2221

Second Semi-Annual Technical Report

Reporting Period: 1 January 1973 to 29 June 1973





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13 ABSTRACT

Ring width chronologies are obtained from sites throughout North America and Europe. When the network of sites has sufficient aeral coverage the hemisphere-wide variations in the recorded climate will be calibrated with variations in growth and these calibrations used to reconstruct past climate for time periods when tree-ring data are available but climatic data do not exist. Progress on collection and processing of data is described and developing plans for international cooperative efforts are discussed.

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SUMMARY (non-technical)

The object of this project is reconstruction of climatic patterns of the past using tree rings, pollen, and other proxy series, as well as climatic data from the Northern Hemisphere. Plans for work at the Laboratory of Tree-Ring Research during 1972-1973 included primarily the collection, processing and preliminary analysis of tree-ring data from North America, collection of historical data such as long climatic records, and the calibration of tree-growth patterns with the synoptic patterns of climate.

Virtually all the tree-ring collections made before May, 1973 from North America (southwestern, midwestern, northeastern, and southeastern United States, Alaska, and Mexico) have been analyzed, along with collections from Sweden. In addition, scanning of materials from other collections made available to the project has been completed and preliminary processing of these materials is under way. A data bank of climatological information has been accumulated for a network of stations west of Meridian 100 and prepared for use in calibration with tree-growth data. Climatic reconstructions made to date cover parts of North America, the North Pacific, and Eastern Asia back to A.D. 1700. Currently reconstructions for the northern areas are being tested against independent tree-growth data.

Visits by H. C. Fritts with scientists in Europe and a series of letters to foreign scientists have both exposed and developed interest in tree-ring based paleoclimatic reconstruction on a world-wide basis. The development of a bank of tree-ring data and the standardization of computational techniques to implement this work are subjects of meetings and workshops planned for the near future.

INTRODUCTION

With growing awareness that climate does change, that man has an impact on climate, and that climate, in turn, has an impact on man, it is important to document the characteristics of past climates and past climatic changes. Climatic change occurs on all time scales, but our knowledge of the spatial and temporal character of climatic change becomes less accurate as we work back from the present. In order to obtain climatic information on the time prior to meteorological observations, it is necessary to rely on proxy records, i.e., environmental chronologies that reflect in some manner the changing climate. Fritts et al. (1971) have shown that ring-width patterns over a large spatial area, such as North America, can be calibrated with climatic data and the calibrated relationship used to estimate climate of the past from the corresponding patterns in tree rings.

The object of this study is to expand the tree-ring and other data base beyond western North America (Fritts et al., 1971) to include eastern North America, the Arctic, Europe, and possibly the Asiatic sector. Collections outside the United States are to be obtained through collaboration with nationals of the particular countries. These data will be applied to climatic information for the Northern Hemisphere to make reconstructions of past variation on a hemispheric scale. Other evidence for past climatic variation is to be used to test independently and improve the reconstructions derived from tree rings.

The work has been divided into four initial tasks. Task 1 is the search for suitable materials to the south of the existing grid into Mexico. Task 2 is an intensive sampling of a grid of living tree sites to match the archaeological chronologies in the Plateau Area of the Southwest. Task 3

is the extension of collection sites into eastern North America and areas of the Arctic and Europe, and has been subdivided into a) collections in eastern United States and b) European and other collaborative work. Task 4 is the development of a data bank of tree-ring and climate materials along with a file of historical and other proxy data. As the data become more available over wider geographical areas, the models being developed under NSF grant GA-26581 will be applied to estimates of climatic variation for the hemisphere.

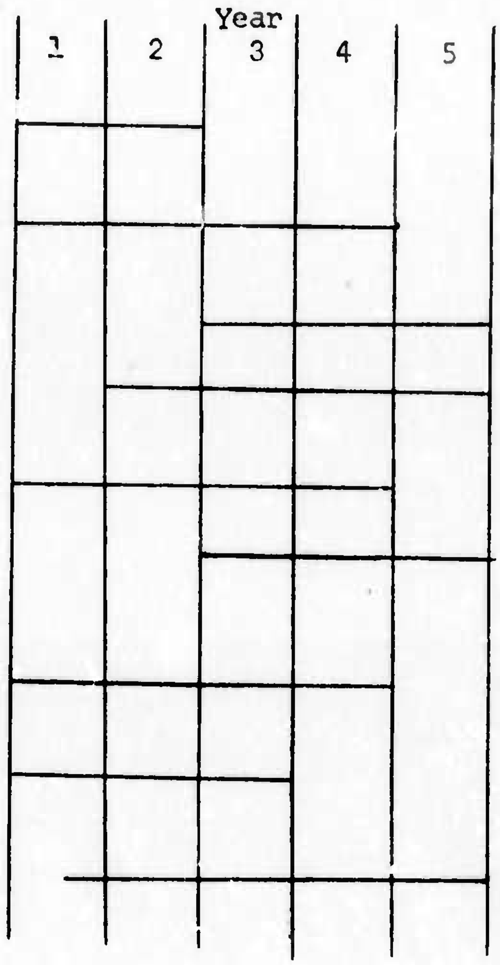
ACCOMPLISHMENTS

The first year of the projected five-year plan for reconstructing past climates has proceeded smoothly and according to schedule. Virtually all of the tree-ring collections from sites in western North America have been completed (see Table 1, item 1, Timing, from the 1972-1973 proposal), including Task 1 materials from northern Mexico and the Rocky Mountains and the concentrated Task 2 materials from the southwestern Plateau Area. Dating and processing of these western collections will be complete well within the second year, per schedule.

Analysis of Task 3 specimens collected in other parts of North America (Table 1, item 2), including sites in New England and northern Minnesota reported in the January 1973 Semi-Annual Report, is in all cases either complete or nearly so. The Mississippi drainage collection acquired from the University of Chicago has been fully scanned for useful material in 4 states thus far and 14 of the sites represented are being prepared and analyzed as potentially useful to the ARPA project. Such prior screening will make greater efficiency possible in a trip planned for July/August, 1973 to update the Chicago collections made 30 years ago. The expansion of tree-ring site coverage into many new areas of North America is thus proceeding as anticipated.

Professional contacts have been made with workers in the midwest and eastern United States and further contacts are scheduled for late summer, 1973, during collecting trips by Fritts to Alaska and by Stockton in the Arkansas-Tennessee region. Meetings have also been held during spring, 1973, with collaborators in Britain and Europe to lay groundwork for data collection and climatic reconstruction on a trans-Atlantic scale.

TABLE 1. TIMING OF DATA COLLECTION AND ANALYSIS (Arizona)
(Proposal of June, 1972)




1. Collect and process ring data from western North America
2. Collect and process data from other areas in North America
3. Process collections for density data
4. Collect and sample ring data from other countries
5. Collect historical information
6. Interpret tree-ring and all other information, including pollen data
7. Development of multivariate and other models
8. Calibrate and relate actual climatic anomalies to synoptic situation
9. Reconstruct past climate

A data bank of climatological information (Table 1, item 5) has been accumulated for a dense network of stations west of Meridian 100. Many of the data are keypunched and ready for use in analysis of tree-growth data. A system for rapid data retrieval has been devised. Other historical climatological data from pre-Weather Service sources are being acquired through library research and incorporated into this system. Plans are being formulated for the possibility of archival research into explorers' journals, microfilmed newspapers, military post and church records from far western United States and northern Mexico during the upcoming year (Table 1, item 5). It is expected that such historical records can be used later as independent tests of our climatic reconstructions.

Additional multivariate models (Table 1, item 7) developed primarily under the auspices of NSF grant GA-26581 are now available for use on the ARPA project and are more fully described in Fritts and Blasing (1973). These multivariate techniques enable us to calibrate spatial anomalies in tree-growth with spatial climatic anomaly patterns (Table 1, item 8) and, using these, to reconstruct the climatic patterns in the past implied by tree-growth anomalies of earlier date. The reconstructions are continually being verified by tests against independent climatic data. Climatic reconstructions (Table 1, item 9) made to date consist of sea-level pressure and by inference temperature, precipitation, and storm frequency over the North American Arctic, western North America, and the North Pacific back to A.D. 1700 (Blasing, unpublished dissertation; Fritts and Blasing, 1973). Currently, reconstructions for the northern areas are being tested against independent tree-growth data from Alaska. Characteristic anomaly patterns of reconstructed sea-level pressure have been classified using a weather-typing scheme in order that changes from one dominant pattern to another

through time may be readily identified (Blasing, unpublished dissertation) Hence, Phase I of climatic reconstruction using annual data is well on the way toward completion by the target date of June, 1974 (Table 2, item 2, in the 1972-1973 proposal).

More detailed reports by the individuals directing each task follow. The four tables following each report contain the progress of analysis on collections made by each task force to date. All new collections made since the January, 1973 report and sites recently made available to the project are included. Several collections previously listed which were found upon analysis to be unsuitable for the ARPA project have been deleted since last reporting.

DETAILED TASK REPORTS

Task 1 reported by M. A. Stokes. Collections in Mexico, Southern California, and Sweden.

Between 17 May and 29 May, 1973 a reconnaissance field trip was made into Baja California del Norte to continue work initiated last summer expanding tree-ring site coverage in Mexico. Two mountainous areas were checked for 1) species available, 2) ring pattern characteristics, and 3) site characteristics.

Two general sites were sampled from the northernmost area, Sierra Juarez. On the Mesa del Pinal two collections were made, one of Perry pinyon (Pinus quadrifolia) and one of Pinus ponderosa. Each set contains a replicated sample of 27 trees. Field observations indicate that there has been much logging throughout the area so that most of the very largest specimens have probably been removed. Some sensitivity was evident in some specimens but no great age can be expected.

The southernmost group was collected from the Sierra San Pedro Martir, which contains the highest elevations in Baja California. Collections represent 5 sites and a total of 85 trees. Species represented in this collection include P. ponderosa, fir (Abies sp.), and incense cedar (Libocedrus decurrens). The latter represent the greatest hope for extreme age in Baja California.

The total collection from Baja California, roughly 300 cores (Table 2), will provide a fair representation of the dendrochronologic potential of that area. A total of 8 of the previously reported sites for Task 1 have been found to be of possible use in the ARPA project. Collections from Santa Fe del Pino, Sierra de Madera, and Saltillo, Mexico, formerly reported in the First Semi-Annual Report of January, 1973, have been deleted because of prob-

lems with false rings, lack of sufficient replication, and inadequate series length. Four of the Swedish collections are being added to and will be usable for the project as our predictions expand into the area of northern Europe and the North Atlantic.

All analysis will be completed by the end of the next year, at which time Task 1 will be accomplished.

Table 2.--Progress of Task 1. Collections in Mexico, Southern California and Sweden

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| ARPA | Sierra del Carmen/ Madera Canyon A, Coahuila | DF | 26/14 | X | X | 1675-1971 | X | X | |
| " | Sierra del Carmen/ Madera Canyon B, Coahuila | MWP | 14/6 | X | X | 1676-1971 | X | X | |
| " | Sierra del Carmen/ Madera Canyon C, Coahila | PP | 13/7 | X | X | 1782-1971 | X | X | |
| " | Sierra del Carmen/ Cojos Canyon Coahuila | PNN | 18/10 | X | X | 1827-1971 | X | X | |
| " | Sierra del Nido B1, Chichuahua | DF | 11/6 | X | X | 1569-1971 | X | X | |
| " | Sierra del Nido B2, Chihuahua | MWP | 7/4 | X | X | 1634-1971 | X | X | |
| " | Sierra Madre, Creel Airport, Chihuahua | DF | 21/11 | X | X | 1642-1972 | X | X | |
| " | Sierra Madre, Rio Oteros, Chihuahua | CS | 21/10 | X | X | 1753-1972 | X | X | |
| " | Baja/N/Topo | PP | 50/25 | | | | | | |
| " | Baja/N/Pond | PNN | 58/29 | | | | | | |
| " | Baja/C/SPM-L | PP | 46/23 | | | | | | |
| " | Baja/C/VALL | PP | 34/17 | | | | | | |
| " | Baja/C/Tasajera | PP | 32/16 | | | | | | |
| " | Baja/C/Tasajera | WF | 30/15 | | | | | | |

DF-Douglas fir; MWP-Mexican white pine; PP-Ponderosa pine; PNN-Mexican pinyon pine; SCP-Scotch pine; CS-Chihuahua spruce; BCS-Big cone spruce, WF-White fir; LD- Incense cedar (*Libocedrus decurrens*).

Table 2.--continued.

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| ARPA | Baja/C/Tasajera | LD | 30/15 | | | | | | |
| R. Tosh | San Gorgonio Mtns. S. California | LBP | 238/101 | X | X | 18 B.C.-1971 | X | X | |
| A. Douglas | Santa Ana Mtns, S. Cal. | BCS | 36/18 | X | X | 1610-1972 | X | X | 30/15 |
| Harlan & Jonsson | Muddas National Park, Sweden | SCP | 7/5 | X | X | 1647-1971 | X | X | |
| Harlan & Jonsson | Muddas National Park, Site A, Sweden | SCP | 13/11 | X | X | 1572-1971 | X | X | |
| Harlan | Östersund, Sweden | SCP | 30/14 | X | X | 1670-1971 | X | X | |
| Harlan & Jonsson | Arosjak, Sweden | SCP | 8/7 | X | X | 1614-1971 | X | X | |

DF-Douglas fir;MWP-Mexican white pine; PP-Ponderosa pine; PNN-Mexican pinyon pine; SCP-Scotch pine; CS-Chihuahua spruce; BCS-Big cone spruce, WF-White fir; LD-Incense cedar (Libocedrus decurrens).

Task 2 reported by Jeffrey S. Dean. Collections in the Southwest Plateau Area.

The principal objective of Task 2 is the construction of a geographical network of tree-ring chronology stations throughout the plateau area of the Southwest in order to assess the tree growth-climate relationships and to isolate spatial and temporal patterns of variation in past climatic conditions in the region. The network of modern stations corresponds to an already existing grid of tree-ring chronologies based on samples from archaeological sites. Dendroclimatic analyses of the modern tree-ring series will be used to calibrate the archaeological sequences with local climatic conditions as a basis for more accurate reconstructions of past climatic variability in the Southwest. Those modern series that extend far enough back into the past will be merged with their archaeological counterparts to produce continuous long-range chronologies suitable for detailed studies of climatic conditions in the Southwest from A.D. 700 to the present.

During the past six months, fifteen previously unsampled tree-growth sites in New Mexico were collected to complete the grid of modern tree-ring chronology stations which is the principal objective of Task 2. The 756 cores collected from 375 trees in New Mexico bring the total amount of material available to the Task 2 research project to 1555 cores from 773 trees representing 46 study sites in Arizona, New Mexico, Colorado, and Utah (Table 3).

Laboratory study of the Task 2 collections proceeded on schedule during 1973. Sample analysis was completed on material from 10 stations, computer analysis of the data from 8 of these site collections is in progress. As of June 1973, specimen analysis has been completed for 22 sites. Seventeen individual species chronologies from 12 sites have been constructed and

six additional dated species sets are in various stages of computer processing. Some additional collections are planned for a few previously sampled sites in Colorado, Arizona, and New Mexico that have statistical or chronological deficiencies, but with analysis of these, the collection of data for Task 2 shall be completed.

Six of the modern chronologies constructed as part of the Task 2 program are long enough to overlap with their archaeological counterparts to yield continuous chronologies that extend from the prehistoric past up to the 1970s. The areas for which we now have continuous coverage are Tsegi Canyon, Hopi Mesas, and Flagstaff in Arizona, Natural Bridges in Utah, and Gobernador in New Mexico. Collection and collation of climatic data to be used in dendroclimatic studies of the relationships between modern tree growth and climate are now under way.

By the end of the second year, a suitable network of standardized tree-ring chronologies will be available and we expect to begin the task of calibration with climate. These calibrations will be used to specify past climate from anomalies in growth. This will proceed in three phases: first, calibrations will use living trees; second, the living-tree chronologies will be compared to the archaeological tree-ring chronologies; and third, these will be used to push the reconstructions of climate of the local areas back to A.D. 700.

Furthermore, the Task 2 tree-ring sequences can be incorporated into larger geographic chronology grids to provide paleoclimatic data on a continental or hemispherical scale.

TABLE 3
Progress of Task 2. Collections on the Southwest Platean Area

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| ARPA | Grasshopper, Ariz. | PP | 36/18 | X | X | 1641-1972 | X | X | |
| ARPA | Salt River Draw, Az. | PP | 21/10 | X | X | 1675-1972 | X | X | |
| ARPA | Oak Creek, Ariz. | PNN | 30/15 | X | X | 1694-1972 | X | X | |
| NPS* ARPA | Spider Rock, Ariz. | PNN | 46/23 | X | X | 1601-1972 | X | X | |
| NPS ARPA | Spider Rock, Ariz. | DF | 32/16 | X | X | 1598-1972 | X | X | |
| NPS ARPA | Canyon de Chelly, Az. | DF | 20/7 | X | X | 1375-1972 | X | X | |
| ARPA | Tseh Ya Kin Canyon, Arizona | DF | 24/12 | X | X | 1500-1972 | X | X | |
| NPS ARPA | Tsegi Point, Ariz. | PNN | 40/20 | | | | | | |
| NPS | Tsegi Point, Ariz. | DF | 14/7 | X | X | 1532-1971 | X | | |
| ARPA NPS, TRL* | Betatakin Canyon, Az. | DF | 77/24 | X | X | 1382-1972 | | | |
| NPS ARPA | Kinbiko Rim, Ariz. | JUN | 22/11 | X | | 1672-1972 | | | |
| NPS | Kinbiko Rim, Ariz. | PNN | 18/9 | | | | | | |
| TRL | Kiet Siel Canyon, Az. | DF | 48/12 | | | | | | |
| NPS | Northern Black Mesa, Arizona | DF | 12/6 | X | X | 1551-1968 | X | | |

Table 3.-- continued

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| NPS | Northern Black Mesa, Arizona | PP | 16/8 | X | X | 1569-1968 | X | | |
| NPS | Northern Black Mesa, Arizona | PNN | 8/4 | X | X | 1600-1968 | X | X | 8/4 |
| TRL | Dinnebito, Arizona | PNN | 44/20 | X | X | 1470-1972 | X | | |
| ARPA | Shonto Plateau, Az. | PNN | 30/15 | X | X | 1369-1972 | | | |
| ARPA | Show Low, Arizona | PP | 30/15 | | | | | | |
| ARPA | Jack's Canyon, Ariz. | PNN | 30/15 | | | | | | |
| ARPA | Robinson Mt., Ariz. | PP | 30/15 | | | | | | |
| ARPA | Medicine Valley, Az. | PP | 30/15 | X | | | | | |
| ARPA | White Horse Hills, Arizona | PP | 30/15 | | | | | | |
| ARPA | Hunting Station, Az. | PNN | 30/15 | X | X | 1717-1972 | | | |
| ARPA | Slate Mt., Ariz. | PP | 24/12 | | | | | | |
| ARPA | Navajo Mt., Utah | PP | 30/15 | X | X | 1566-1972 | | | |
| ARPA | Navajo Mt., Utah | PNN | 26/13 | X | X | 1468-1972 | | | |
| ARPA | Kane Spring, Utah | PNN | 30/15 | X | X | 1444-1972 | X | | |
| ARPA | White Canyon, Utah | DF | 42/21 | X | X | 1346-1972 | | | |

Table 3. - continued

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| USFS* | Elk Ridge, Utah | PNN | 20/10 | | | | | | |
| USFS | Elk Ridge, Utah | JUN | 10/5 | | | | | | |
| USFS | Devil's Canyon, Utah | PP | 12/6 | | | | | | |
| MNA* | Cedar Mesa, Utah | PNN<br>JUN | 96<br>Sections | X | X | 1491-1972 | | | |
| ARPA | Bobcat Canyon, Colo. | DF | 24/12 | X | X | 1388-1972 | X | X | |
| ARPA | Wetherill Mesa, Col. | PNN | 24/12 | X | X | 1611-1972 | X | X | |
| ARPA | Wetherill Mesa, Col. | JUN | 16/8 | X | X | 1817-1972 | | | |
| ARPA | Pueblito Canyon, N.M. | DF | 29/14 | X | X | 1651-1972 | X | X | |
| ARPA | Ditch Canyon, N,M. | DF | 28/14 | X | X | 1657-1972 | X | X | 22/11 |
| ARPA | Ditch Canyon, N.M. | PP | 28/14 | X | X | 1554-1972 | X | X | |
| ARPA | Ditch Canyon, N.M. | PNN | 24/12 | X | X | 1574-1972 | X | X | |
| ARPA | Ditch Canyon, N.M. | JUN | 12/6 | X | X | 1692-1972 | | | |
| TRL* | Aztec, N. M. | DF | 12/6 | X | X | 1542-1970 | X | X | 12/6 |
| TRL | Aztec, N. M. | JUN | 12/6 | X | X | 1417-1970 | X | X | 12/6 |
| ARPA | El Morro, N. M. | PP | 70/35 | | | | | | |
| ARPA | El Morro, N. M. | PNN | 40/20 | | | | | | |
| ARPA | Canyon Lob, N.M. | PNN | 40/20 | | | | | | |

Table 3. - continued

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| NPS* ARPA | Satan's Pass, N.M. | DF | 54/27 | | | | | | |
| NPS ARPA | Turkey Spring, N.M. | PP | 52/26 | | | | | | |
| NPS ARPA | Turkey Spring, N.M. | PNN | 40/20 | | | | | | |
| NPS ARPA | Fort Wingate, N.M. | PNN | 52/26 | | | | | | |
| ARPA | Mt. Taylor, N.M. | PNN | 40/20 | | | | | | |
| ARPA | Cebolleta, N.M. | PNN | 42/21 | | | | | | |
| ARPA | Agua Fria, N.M. | PNN | 40/20 | | | | | | |
| ARPA | Tajique Canyon, N.M. | PP | 32/16 | | | | | | |
| ARPA | Tajique Canyon, N.M. | PNN | 24/12 | | | | | | |
| ARPA | Paliza, N. M. | PNN | 28/14 | | | | | | |
| NPS ARPA | Echo Amphitheater, N.M. | DF | 34/13 | | | | | | |
| ARPA | Glorieta Mesa, N.M. | PNN | 30/15 | | | | | | |
| ARPA | Ruidosa Ridge, N.M. | DF | 42/21 | | | | | | |

Table 3 - continued

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| ARPA | Ruidosa Ridge, N.M. | PNN | 30/15 | | | | | | |
| ARPA | Rito de los Frijoles, N.M. | PP | 36/18 | | | | | | |
| ARPA | El Valle, N. M. | PP | 32/16 | | | | | | |

PP-Ponderosa pine; PNN-Colorado pinyon pine; DF-Douglas fir; JUN-Juniper

*USFS-U. S. Forest Service; MNA-Museum of Northern Arizona; TRL-Tree-Ring Laboratory; NPS-National Park Service

Task 3a reported by M. A. Wiseman. Collections in Northeastern, Midwestern, and Southeastern United States.

Tree-ring collections made in the midwestern and eastern sectors have proven to contain data useful for long-term reconstruction. Those from New England reported in January, 1973 are almost complete through data processing (Table 4). An additional set of collections from northern Vermont has been made available by Dr. Thomas Siccama of the Yale School of Forest Ecology. The New England materials often have unusual growth curves so their analysis awaits the completion of a new curve-filling option in the computer program used to standardize data. The collections from northern Minnesota are dated and are being measured. The sites are strategically located and the materials show sufficient length to make them particularly valuable in our ARPA work.

In order to determine which sites represented in the University of Chicago collection might be climatically responsive and have adequate series length, a total of 34 sites in Tennessee, Missouri, Arkansas, and Oklahoma have been scanned (Table 4). Twenty-one sites of white oak (Quercus alba), short-leaf pine (Pinus echinata), hemlock (Tsuga canadensis), and eastern red cedar (Juniperus virginiana) may prove profitable when updated with materials to be re-collected from the respective sites. A collection trip is planned to these areas in late July - early August, 1973.

A preliminary computer analysis was run on a set of eastern red cedar from Jefferson County, Missouri (Mo-Je), to determine how this species responds to climatic parameters and how useful it may be in reconstructing past climate. There is sufficient climatic information in the rings of this species, but great difficulty with crossdating suggests that cedar may be less

promising than other species for which the dating is more reliable. Further work on cedar is planned using Norris Basin materials; however, our primary efforts will be directed toward developing chronologies of other species in the East, particularly the oaks.

.ble 4.--Progress of Task 3. Collections in northeast, midwest and southeastern United States

| PONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| RPA | Nancy Brook, N.H. | RS | 36/18 | X | X | 1561-1972 | X | X | |
| " | Livingston, Mass. | RS | 31/15 | X | X | 1696-1972 | X | X | |
| :iccama | Camel's Hump A, Vt. | RS | 22/11 | X | X | 1687-1972 | X | | |
| " | Camel's Hump B | RS | 15/8 | X | X | 1778-1972 | X | | |
| " | Camel's Hump C | RS | 16/8 | X | X | 1635-1972 | X | | |
| RPA | Seagull Lake, Minn. | RP | 58/30 | X | | | | | |
| " | Saganaga Lake, Minn. | RP | 117/63 | X | X | 1671-1971 | X | | |
| " | Itasca St. Park, Minn. | RP | 53/27 | X | | | | | |
| ı. of Chicago :ollection | | | | | | | | | |
| | Arkansas | | | | | | | | |
| " | A-Bo | oak | 26 | X | | ca 1700-1940 | | | |
| " | A-In | WO | 27 | X | | ca 1640-1940 | | | |
| " | A-Jo | WO | 39 | X | | ca 1690-1940 | | | |
| " | A-Ma | oak | 25 | X | | ca 1770-1940 | | | |
| " | A-Mc | pine | 45 | X | | ca 1640-1940 | | | |
| " | A-Ne | WO | 49 | X | | ca 1680-1940 | | | |
| " | A-Po | pine | 44 | X | | ca 1640-1940 | | | |
| | | WO | | X | | ca 1690-1940 | | | |

ЗS-red spruce; RP-red pine; WO-white oak; SLP-shortleaf pine; ERC-eastern red cedar

.e 4.--continued.

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| l. of Chicago Collection, Arkansas (con'd.) | | | | | | | | | |
| | A-Pp | WO | 61 | X | | ca 1680-1940 | | | |
| " | A-Ye | SLP | 7 | X | | ca 1730-1940 | | | |
| | Missouri | | | | | | | | |
| " | Mo-Ct | WO | 45 | X | | ca 1690-1940 | | | |
| " | Mo-Je | ERC | 103 | 36 | X | 1746-1942 | X | X | |
| " | Mo-S | oak | 106 | X | | ca 1715-1940 | | | |
| | | pine | | X | | ca 1690-1940 | | | |
| | Oklahoma | | | | | | | | |
| " | O-Cm | ERC | 32 | X | | ca 1640-1940 | | | |
| | Tennessee | | | | | | | | |
| " | T-An | SLP | 6 | X | | 1719-1938 | | | |
| " | T-Br | pine | 114 | X | | ca 1745-1938 | | | |
| " | T-Cu | SLP | 5 | X | | ca 1840-1940 | | | |
| " | T-Se | HM | 13 | X | | ca 1740-1940 | | | |
| " | T-Wa | oak | 25 | X | | ca 1715-1938 | | | |
| " | Norris Basin | ERC | 215 | 27 | X | 1752-1934 | | | |

WO-white oak; ERC-eastern red cedar; HN-hemlock, SLP-shortleaf pine

Task 3b reported by H. C. Fritts. International Cooperation.

The work of obtaining ring data produced in other countries has begun with the circulation of a letter in January, 1973 to more than 150 scientists throughout the world (see Appendix). More than 50 scientists replied, and a second letter was sent in April, 1973 (see Appendix). The objective is to establish a collaborative international effort with non-American counterparts who will collect and process the data from their areas of interest. In order to encourage the work, the Laboratory of Tree-Ring Research will supply appropriate computer programs, chronologies from North America, and technical help when solicited. No actual research is planned for this task outside the borders of the United States.

H. C. Fritts visited scientists in England, Northern Ireland, Sweden, Germany, Belgium, Czechoslovakia, and Israel to report on current work and to discuss details on the structure required to accomplish the task. The report of his trip follows.

England. May 15-22, 1973. Discussions were held with Dr. John Kutzbach (principal investigator for our collaborative ARPA proposal at the University of Wisconsin) and Dr. H. H. Lamb at Norwich, England regarding more intensive studies of yearly fluctuations in climate. Several approaches were considered and suggestions were made as to new contacts and a data series. Also six days were spent in the CLIMAP workshop being held at the same time on the climate of the glacial maximum.

Northern Ireland. May 22-26, 1973. Expenses from England to Belfast and return were paid by Belfast University. Discussions with Dr. A. G. Smith, Dr. John Pilcher, and Dr. M. G. L. Baillie centered around ways of developing chronologies from living trees and from archaeological materials. A ground plan for their work was set up and arrangements were made for sharing in-

formation on techniques.

Hamburg, Germany. May 26-28, 1973. Discussions, primarily with Dr. D. Eckstein, Dr. J. Bauch, and Dr. W. Liese, centered about a) the establishment of a collaborative group in Europe, b) the establishment of a world tree-ring data bank, and c) the initiation of a preliminary multivariate analysis of available data to demonstrate the usefulness of the technique. Eckstein planned to send several sets of data and as one of the European centers pledged his support of the data bank.

Stockholm, Sweden. May 26 - June 3, 1973. Discussions with Dr. Bengt Jonsson and Professor G. Sirén centered about the same three topics. Jonsson, who had already helped with the Sweden chronologies, proposed additional collection and evolved a plan to test the usability of existing data on call from computer tape at the Royal College of Forestry. Sirén offered materials from Lapland and described a new project to be initiated this summer in Gotland. They hoped to operate the data bank for the Scandanavian area.

Travel plans to the U.S.S.R. were deleted because of restrictions that were in effect during that time.

Prague, Czechoslovakia. June 3-5, 1973. Discussions were primarily with Professor B. Vinš. Very important new contacts were established and we talked of dendroclimatic sampling and possibilities for a data bank there to serve southeastern Europe. Contact was made with a dendrochronologist, Valdimir Židek.

Stuttgart, Germany. June 5-7, 1973. Dr. B. Becker spent time describing his work and discussing the three matters mentioned above. He considered the idea of a data bank an excellent opportunity for him to make available to the scientists of the world the work of Professor Huber, the father of

European dendrochronology. He also promised several contributions of his own.

Louvain, Belgium. June 7-9, 1973. Discussions with Dr. A. Munaut and Dr. André Berger centered around the problem of funding work in small European countries that are apparently not able to support work on problems of world-wide variations in climate. He described his plans to sample trees in Morocco for the purpose of large-scale climatic reconstruction work.

Tel Aviv, Israel. June 9-13, 1973. The visit with Professor Y. Waisel centered around the development of basic facilities and analysis of materials from very old Juniperus from the Negev. Waisel also had collected in some of the Mediterranean islands and planned to work in other countries of the Middle East. Fritts offered the help of the Laboratory of Tree-Ring Research in trying to resolve problems of dating juniper because this species appeared to have highly variable ring widths. Time was also spent with Professor G. Orshan and Dr. A. Danin at Hebrew University.

Return to U.S. via Washington, D. C. June 13, 1973. Dr. Richard Phipps of the Geological Survey expressed an interest in the cooperative program.

On return to Tucson a draft copy of the purposes and procedures for the International Data Bank was drawn up, a memorandum regarding the preliminary analysis of European data was composed, and other materials on computer analysis were prepared for submission to the European counterparts.

Considerable interest was expressed in data sharing, standardizing of techniques, and specific plans for meetings and workshops in the near future. Many offered data to be used in a demonstration analysis and all expressed their interest in increasing efforts directed at obtaining long tree-ring chronologies for climatic reconstruction purposes. In part, the success of the European visits was a direct result of the significant progress I was

able to report on the work supported by both ARPA and the National Science Foundation. Increased efforts will be directed toward further development of cooperation in dendroclimatology throughout the world.

Task 4 reported by Charles W. Stockton. Climatic Data Bank and Collections from Western United States.

Our climatic data bank now consists of a preliminary network of stations west of the 100th Meridian which will be finalized in the near future. We have scanned through a set of over 200 station records of monthly precipitation and temperature and have selected a tentative grid of 33 climatic stations. These were chosen on the basis of duration of record and proximity to sites in our existing tree-ring network. We have chosen the longest consistent records we could find, including those from old forts, within the spatial array of the tree-ring network. All stations have at least 50 years of data but most have closer to 70 years or more. These data are to be used to calibrate against the tree-ring data in reconstructions. The precipitation data is currently undergoing testing for homogeneity using the double-mass analysis technique, and temperature data is being checked using a modified first-difference procedure.

As soon as the climatic grid west of Meridian 100 is finished, we will begin compiling a similar grid east of that longitude. The eastern portion will not be as detailed as that in the West, because there are fewer mountains to interrupt the spatial continuity in the climate of eastern continental United States.

All of the 21 tree-ring chronologies made available to the ARPA project from the Lake Powell, Yellowstone National Park, and other projects have been completely analyzed through data processing (Table 5). Nearly all of the derived chronologies have good length (> 300 years), replication, and sensitivity and thereby meet the qualifications for use in the climatic reconstruction work.

Wood density data indicative of temperature effects on growth should

be forthcoming within the next year as a result of the recent installation of densitometric equipment at the Laboratory of Tree-Ring Research (NSF grant GA-33859, V. C. LaMarche, principal investigator).

Table 5.-- Progress to Task 4. Collections in the Colorado drainage region and Yellowstone National Park

| SPONSOR | SITE NAME | SPECIES | CORES/ TREES | EXAMINED | DATING CHECKED | CHRON. LENGTH | MEASURED | DATA PROCESSED | SELECTED CORES/TREES |
|---|---|---|---|---|---|---|---|---|---|
| Lake Powell Project | Uinta Mtns. A, Utah | ES | 20/10 | X | X | 1433-1971 | X | X | |
| | Uinta Mtns. B. Utah | DF | 20/10 | X | X | 1730-1971 | X | X | |
| " | Uinta Mtns. C, Utah | DF | 18/9 | X | X | 1635-1971 | X | X | |
| " | Uinta Mtns. D, Utah | PNN | 16/8 | X | X | 1423-1971 | X | X | |
| " | Uinta Mtns. (North) | ES | 31/15 | X | X | 1605-1971 | X | X | |
| " | Windriver Mtns., WYO. | DF | 24/12 | X | X | 1568-1971 | X | | |
| " | Windriver Mtns. A | LBP | 22/10 | X | X | 1678-1971 | X | X | |
| " | Windriver Mtns. C | DF | 39/18 | X | X | 1504-1971 | X | X | |
| " | Windriver Mtns. D | LBP | 28/13 | X | X | 1492-1972 | X | X | |
| " | Dolores, Colorado | DF | 22/11 | X | X | 1794-1972 | X | X | |
| " | LaSal Mtns. A | PNN | 22/11 | X | X | 1489-1972 | X | X | |
| Yellow-stone N. P. | Dead Indian Hill, WYO. | DF | 32/16 | X | X | 1300-1971 | X | X | |
| | Gardiner A, Montana | DF | 12/6 | X | X | 1185-1971 | X | X | |
| " | Gardiner B, Montana | LBP | 10/5 | X | X | 1185-1971 | X | X | |
| " | Gros Ventre, WYO. | LBP | 54/27 | X | X | 1462-1971 | X | X | |
| " | Spanish Creek, Mont. | DF | 38/19 | X | X | 1622-1972 | X | X | |
| " | Uhl Hill, Wyoming | LBP | 16/8 | X | X | 1450-1972 | X | X | |
| J. Yu | Rincon Peak, Az. | DF | 22/11 | X | X | ca 1600-1972 | X | X | |

ES-Engelmann spruce; DF-Douglas fir; PNN- Colorado pinyon pine; LBP-Limber pine

# APPENDIX

The first and second letters sent to scientists regarding possibilities for an international working group on dendroclimatology.

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

LABORATORY OF TREE-RING RESEARCH

January 1973

Dear Colleague:

Much scientific attention is being directed to climatic research and to the modeling of climate in order to forecast both natural and inadvertent climatic change. The Global Atmosphere Research Program (GARP), an international organization, is one such effort investigating and modeling the circulation of the earth's atmosphere. An important limitation to present modeling attempts is that they are dependent upon the relatively short historical records of climate. Considerable evidence has accumulated that the climate of the historical period is significantly different from that of the past. A lengthened record, even extending as little as 200 to 300 years back in time, could provide better estimates of future variability in the earth's circulation and contribute significantly to improved prediction of man's future climates.

Ring-width chronologies from trees can provide some of the information needed because the annual record of growth can be precisely dated and the ring widths or other features of the wood can be calibrated with climatic conditions of the sites that have affected tree growth. A set of ring-width chronologies based upon hundreds of trees from 49 locations in western North America has been used to specify and map modes of atmosphere circulation over the North Pacific and North America (See Journal of Applied Meteorology, Vol. 10, pp. 845-864). Reconstructions over the Atlantic Ocean were less reliable. However, it appears from the results of more recent work that an expansion of the grid of tree-ring stations to eastern North America and Canada will allow reconstruction of the atmosphere circulation over western portions of the North Atlantic Ocean as well. If ring chronologies can be added from Europe and Asia, there is every reason to believe that reconstructions of the past atmosphere circulation, precipitation and temperature can be made for many areas over significant portions of the Northern Hemisphere.

I am, therefore, writing to ask whether you might be interested in working on a long-term cooperative effort aimed at providing such reconstructions of past climate of the Northern Hemisphere. Such a project might involve a concentrated effort to seek out long and well replicated sequences of ring-width variability in your area. Many of you may already have materials in your collections that could be processed to provide the necessary chronologies. There also may be well dated proxy series of climate other than ring-widths such as varves or vintage dates that can be included as well.

Although associated climatic data are useful for calibration purposes, not all the tree sites need to be collected near a weather station. The samples should be replicated (to include a number of trees), the rings dated, and the chronologies suitably processed. The relationship between departures from mean ring width and departures in regional climatic factors can be obtained by multivariate techniques. Transfer functions are obtained which serve as calibration and these functions are applied to ring widths formed in past years to reconstruct or estimate the corresponding year's climate.

This letter is a first step to ascertain which scientists might be interested and able to work on such a project. If you are interested or know of anyone anywhere who would be both qualified and able to participate, I would be very pleased to hear from you. It is my hope that we can start to achieve some sort of communication such as sharing ideas or pertinent results through a newsletter. Perhaps we could then begin working towards an international workshop on the subject of dendroclimatology where it will be possible to discuss various approaches. Once we are brought together, it may be possible to draft some agreement for carrying out joint research. There is also a good possibility that some international focus and backing might be obtained.

Lest I arouse your hopes too quickly, this is only a first and preliminary inquiry. No support is yet committed to such a project, although the Laboratory of Tree-Ring Research is now on a program aimed at accumulating tree-ring chronologies from areas of eastern and northern North America and preliminary inquiries are being made regarding support for an international workshop. I think it is safe to say that the prospects are good for support of tree-ring work as the meteorological world is becoming more aware of the potential information in tree rings and its usefulness to their work.

The question now is whether tree-ring scientists are sufficiently interested, whether they would accept the challenge of such an international effort and whether there are a sufficient number of us to carry out the task. Could we standardize our methods sufficiently to be able to utilize each other's data or are the objectives of our various researches too different to be accommodated? If this problem is of interest, would you give it some serious consideration and discussion and send me your reactions? The need for some sort of plan is great and would appear essential. Also such an effort will succeed only if interest is coupled with an honest and realistic assessment of each individual's time and resources that might be available for such a project. In order to start things moving, I will try to synthesize the response and in a month or so will circulate a second communication to those expressing a direct interest.

In hopes that I shall hear from you soon, I am

Sincerely yours,

Harold C Fritts

Harold C. Fritts
Professor of Dendrochronology

HCF:aa

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

LABORATORY OF TREE-RING RESEARCH

Dear Colleague:

This is a second letter sent only to those who have replied and expressed interest in a cooperative project in dendrochronology. At the end of this letter is a list of the interested recipients. I hope no mistakes or omissions have been made. If so, please let us know promptly.

In the initial inquiry I mistakenly restricted our concern to paleoclimatic reconstruction of the Northern Hemisphere. We now realize that this must be broadened to include both hemispheres. There is much interest in research on possible interactions between the Northern and Southern Hemispheres. Dr. Valmore LaMarche also recently has found excellent tree-ring climatic relationships in central Chile. He is planning a broad study of the dendrochronology and dendroclimatology of the Southern Hemisphere and those of you who might be interested in direct participation in the program might wish to write him. Certainly, our cooperative group will eventually have to deal with the chronologies for the entire world.

My reference to the Global Atmospheric Research Program did not imply that the proposal is at this moment an official program of GARP. At present, it is not, but I sincerely hope that we can initiate a joint effort which will eventually become a part of GARP. Inquiries have been made to the U. S. committee and a recommendation should be submitted to them in due time. Until that is accomplished through official channels, we should not consider our efforts at present as a GARP project. However, we can perhaps show them that there is genuine interest in the work.

Professor Frenzel writes that he is hoping to arrange a symposium on dendrochronology and dendroclimatology early in October or later in the year, perhaps sponsored by the Academy of Science and Literature in Mainz. Anyone interested in such a meeting might write him.

Professor A. G. Smith writes of his interest in the cooperative program but expresses concern as to 1) the extent it would be necessary to modify existing programs, 2) the additional time it would take to get data into acceptable form, 3) the availability of staff (at his institution), 4) the availability of funds, and 5) whether there will be sufficient return to justify the effort invested in international cooperation. These and other concerns are on many of our minds, and it will be these very questions that must be dealt with

before we can obtain the desired feeling of cooperation. We at the Laboratory of Tree-Ring Research can provide some technical assistance, and perhaps moral support in applications by others. No single group has all the answers. Perhaps we could consider our endeavor as a search for approaches and techniques which will best serve our science.

In addition to replies concerning the numerous studies in Europe, Robert W. Buddemeier reports that density changes of coral near Hawaii seem to act like tree rings and could provide needed information on climates of the tropics He suspects these organisms are responding to light and cloud cover during the winter.

We are finishing the first year of a project aimed at extending our tree-ring chronologies into eastern North America. Marion Parker is in hopes that his country will be interested in supporting work in the Canadian Arctic. Several have already offered or sent chronologies for places in Europe and Scandinavia. Progress is also being made using x-rays.

Some of you have expressed interest but admit limited experience. Some are asking for directions. It really is most difficult to describe the science adequately with a set of directions. May I recommend that one first become acquainted with the literature. I can supply some reprints on the Arizona work. Perhaps we should make bibliographies to be circulated among us.

I shall offer the general and oversimplified statement that if one can obtain cross-dating over moderately large areas, then one is likely to have climatic information in tree rings. If the patterns do not cross-date among neighboring trees, then it is probable that climate is not sufficiently limiting to growth to produce a record of climate in the rings. The best start is to sample trees, look at the rings, and see what you find. I am working on a treatise of dendroclimatology and, with some luck, it could be in the hands of Academic Press (London) by mid 1974. Perhaps this will help meet some of the need. Until then we will have to rely on our correspondences.

Roger Bray is the skeptic. He questions whether there is sufficient information in single trees and thinks that one must sample the entire ecosystem. He is correct that data must be collected from many trees in an area so that there is adequate replication but only in the case where climate is very weakly limiting would it be necessary to sample a whole ecosystem. In cases where climate is a very important factor producing large variations in ring structure, one can utilize as few as 10 trees and still retain a fairly reliable climatic record with not too large a statistical error. However, for many areas 20, 30 or more trees will be needed to obtain a reasonably low error. It is natural that Bray, who is a biologist, recognizes all the possible limiting conditions to growth. However, we need not use any or all trees, only a sample of trees that are sufficiently limited by the same climatic factors to yield a past record of climate in a particular site. One can also sample different sites, treating each site (with replications of trees within the site) as a separate sample. If the trees on different sites respond to different climatic factors, we can still utilize them in climatic reconstruction as the multivariate equation allows for differences in climatic information and actually utilizes differences to gain information on past environments (see Journal of Applied Meteorology, Vol. 10, pages 845-864).

A research proposal and report of progress in our research at the Laboratory of Tree-Ring Research is available in very limited supply. It is entitled "Tree-Ring Analysis of Environmental Variability: An Extended Basis for Evaluating Inadvertent and Natural Climatic Change." Another lengthy manuscript has been prepared but is not available in quantity--"Relationships of Ring Widths in Arid-Site Conifers to Variations in Monthly Temperature and Precipitation." Three volumes of chronologies from areas of western North America are available, again in limited supply, but these publications can be sent to those who need them.

I shall hope to see some of you in May or June on my visit to Europe and will look forward to your correspondence. On my return to Tucson, I shall try to send a third letter describing new developments. Let me hear from you if there are any more comments, developments or items to put in the next letter.

Sincerely,

Harold C Fritts

Harold C. Fritts
Professor of Dendrochronology

HCF:rsf

Professor Jouko Alestalo
Institute of Geography
University of Oulu
Oulu, Finland

Dr. B. Becker
Botanisches Institut
Der Universität Hohenheim
7000 Stuttgart-Hohenheim
West Germany

Dr. Roger J. Bray
P. O. Box 494
Nelson
New Zealand

Dr. Robert W. Buddemeier
Hawaii Institute of Geophysics
University of Hawaii
Honolulu, Hawaii 96822

Prof. Dr. M. I. Budyko
Main Geophysical Observatory
Leningrad, M. Spasskaja, 7
U.S.S.R.

Dr. M. S. Czarnowski, Docent
IUFRO
Laboratory of Ecology and Geography of Plants
Wroclaw University
Kanonia Street 6-8
Wroclaw, Poland

Professor Pierre de Martin
Université de Paris - Sorbonne
U. E.R. de Géographie
191, rue Saint-Jacques
75 - Paris V
France

Dr. N. Donita
Institutul de Cercetaru Silvice
sos. Pipera 46
Bucuresti, Romania

Dr. D. Eckstein
Lehrstuhl für Holzwirtschaft
Universität Hamburg
Hamburg
West Germany

Prof. Dr. Karol Ermich
Akademia Rolnicza
Wydzial Leśny
ul. Św. Marka 37
31-024 Kraków
Poland

Dr. H. Faure
Lab. de Geologie Dynamique et Centres
de Récherches Geodynamiques
Univ. de Paris
9, Quai Saint-Bernard
Paris V$^{e}$, France

Dr. David French, Director
British Institute of Archaeology
at Ankara
Tahran Caddesi No. 21
Kavaklidere
Ankara, Turkey

Prof. Dr. B. Frenzel
Botanisches Institut
Der Universität Hohenheim
7000 Stuttgart-Hehenheim
West Germany

Mrs. Veronika Giertz-Siebenlist
Neureutherstr. 5
8 München 13
West Germany

Dr. G. L. Guy
The National Museum of Rhodesia
P. O. Box 90
Selukwe, Rhodesia

Dr. Malcom K. Hughes
Department of Biology
Liverpool Polytechnic
Byron St.
Liverpool L3 3AF
England

Professor Ilmari Hustich
Hollandarv. 1
Helsinki-Munksnas
Finland

Dr. Jerzy Olszewski
Bioclimatological Laboratory of the
Mammals Research Institute
Polish Academy of Sciences
Bialowieza, Poland

Dr. Bengt Jonsson
Department of Forest Yield Research
Royal College of Forestry
Stockholm, Sweden

Dr. John E. Kutzbach
Center for Climatic Research
Department of Meteorology
University of Wisconsin
1225 West Dayton Street
Madison, Wisconsin 53706

Dr. Valmore C. LaMarche, Jr.
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

Mr. V. T. Liu
Taiwan Forestry Research Institute
Botanical Garden, Nan-hai Road
Taipeh, Taiwan
Republic of China

Dr. N. V. Lovelius
Komarov Botanical Institute
Leningrad - 197022
Popova 2
U.S.S.R.

Professor Jay D. McKendrick
Agronomy Department
Institute of Agricultural Sciences
P. O. Box AE
Palmer, Alaska 99645

Dr. E. Medina
Instituto Venezolano de Investigaciones
Cientificas (I.V.I.C.)
Apartado, 1827
Caracas, Venezuela

Dr. André Munaut
Laboratoire de Palynologie et Phytosociolgie
Univ. de Louvain
42, Avenue de Croy
Héverlee-Louvain
Belgium

Dr. G. Orshan
Botany Department
Hebrew University
Jerusalem, Israel

Marion L. Parker
Forest Products Laboratory
Department of Forestry
6620 N. W. Marine Drive
University of British Columbia
Vancouver, B. C., Canada

Dr. Hubert Polge
Centre National de Récherches
Forestières
Forêt d'Amance
54 Champenoux, France

Professor A. Pons
Université de Provence
Laboratoire de Botanique Historique
et Palynologie
Centre de Saint-Jérôme
13 Marseille (13e)
France

Juan Puigdefabregas
Centro Pirenaico de Bíologia Experimental
Apartado, 64
Jaca (Huesca)
Spain

Dr. B. R. Roberts
Faculty of Agriculture
Private Bag X0576
The University of the Orange Free State
P. O. Box 339
Bloemfontein
Republic of South Africa

Dr. Carlos Schubert
Instituto Venesolano de Investigaciones
Cientificas
Apartado, 1827
Caracas, Venezuela

Mlle. F. Serre
Laboratoire de Botanique Historique
et Palynologie
Faculté des Sciences de St. Jérôme
13 Marseille (13e), France

Dr. Thomas J. Sheehy
Soil Scientist
U. S. Department of Agriculture
Forest Service
121 W. Fireweed Lane, Suite 205
Anchorage, Alaska 99503

Dr. A. G. Smith
Palaeoecology Laboratory
Botany Department
University of Belfast
Belfast 7, Northern Ireland

J. D. Torrance, Deputy Director
Department of Meteorological Services
P. O. Box BE150 Belvedere
Salisbury, Rhodesia

Dr. B. Vinš
Forestry and Game Management Research
Institut
Zbraslav n. Vlt.
Strnady 167, Czechoslovakia

Dr. Yoav Waisel
Tel-Aviv University
Department of Botany
155, Herzl St.
68101 Tel-Aviv, Israel

V. S. Wakankar
Department of Archaeology
Vikram University
Bharati Kala Bhawan
Ujjain. M.P., India

Dr. Donald Walker
Department of Biogeography and
Geomorphology
Research School of Pacific Studies
Australian National University
P. O. Box 4
Canberra A.C.T. 2600, Australia

Professor T. T. Wang
Department of Forestry
National Taiwan University
Taipeh, Taiwan
Republic of China

Dr. Frank W. Woods
Department of Forestry
University of Tennessee
Knoxville, Tennessee 37916

Professor Masatoshi Yoshino
Department of Geography
Hosei University
Ichigaya, Shinjuku-ku
Tokyo, Japan

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